The X-Ray View of Femtosecond Magnetism

Hermann A. Dürr

SLAC National Accelerator Laboratory

hdurr@slac.stanford.edu

The interplay between electronic, spin and lattice degrees of freedom often determines the function of complex materials such as high T_C superconductors, colossal magnetoresistive, multiferroic oxides and ferromagnets. The relevant interactions in magnetic solids such as Coulomb, exchange, spin-orbit and electron-phonon interaction are of various strength and lead to different characteristic time scales for energy and angular momentum transfer between orbital, spin and lattice degrees of freedom. Of particular interest for magnetic solids is to understand how and on what timescale the relatively weak spin–orbit coupling can be used to manipulate ferromagnetic order in extreme electromagnetic fields. Such studies are of direct relevance for establishing the ultimate time scale for magnetic switching in future data storage devices.

While the pioneering fs magnetism study with optical lasers 15 years ago observed demagnetization following laser heating of the electron system the use of fs soft x-ray pulses enabled the direct observation of the flow of angular momentum between spins and orbitals. Fs hard x-ray pulses should allow us to probe directly the lattice as an angular momentum reservoir as shown schematically in the figure. New magnetic switching mechanisms are revealed by the use of extremely intense electrical field pulses where the electrical field strength rivals the atomic crystalline field. Understanding the microscopic process will most likely only be revealed by future fs x-ray sources with two-color probe capabilities (see figure below).